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Enumeration of the 1991 Harrison River Chinook Salmon Escapement

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ABSTRACT

Farwell, M.K., N.D. Schubert and L.W. Kalnin. 1992. Enumeration of the 1991 Harrison River chinook salmon escapement. Can. Manuscr. Rep. Fish. Aquat. Sci. 2152: 24 p.

In 1985, the Pacific Salmon Treaty committed the Canadian Department of Fisheries and Oceans to halt the decline in abundance of chinook salmon (*Oncorhynchus tshawytscha*) stocks. The Harrison River was designated a chinook indicator stock, and escapement has been monitored annually since 1984. In 1991, the Harrison River chinook escapement was estimated, using the Petersen mark-recapture method, at 90,638 adults. The sex composition of the escapement was 47% female and 53% male. The age composition of the recovery sample was 18.9% age 3_1, 54.1% age 4_1, and 27.0% age 5_1 for females and 45.3% age 3_1, 37.3% age 4_1, and 17.3% age 5_1 for males.

Key Words: Chinook salmon, Harrison River, indicator stock, escapement, Pacific Salmon Treaty.

RÉSUMÉ

Farwell, M.K., N.D. Schubert and L.W. Kalnin. 1992. Enumeration of the 1991 Harrison River chinook salmon escapement. Can. Manuscr. Rep. Fish. Aquat. Sci. 2152: 24 p.

En 1985, le Traité concernant le saumon du Pacifique a donné comme mission au ministère des Pêches et des Océans du gouvernement canadien de mettre fin à la baisse du saumon quinnat (*Oncorhynchus tshawytscha*). Le stock de la rivière Harrison a été désigné comme stock indicateur de l'état du saumon quinnat et son échappée a fait l'objet d'une surveillance annuelle depuis 1984. En 1991, l'échappée du quinnat dans la rivière Harrison a été évaluée à 90 638 adultes, selon la méthode de marquage et de recapture de Petersen. La composition de la population selon le sexe a été évaluée comme suit: 47% de femelles et 53% mâles. La composition par âge de l'échantillon de récupération était la suivante: 18,9% d'âge 3_1, 54,1% d'âge 4_1, et 27,0% d'âge 5_1 pour femelles et 45,3% d'âge 3_1, 37,3% d'âge 4_1, et 17,3% d'âge 5_1 pour mâles.

Mots cles: Saumon quinnat, rivière Harrison, stock indicateur, échappée, Traité concernant le saumon du Pacifique.

INTRODUCTION

The 1985 Pacific Salmon Treaty committed management agencies in Canada and the United States of America to halt the decline in chinook salmon (*Oncorhynchus tshawytscha*) spawning escapements and to attain, by 1998, escapement goals established by each nation (Anon. 1985). To evaluate rebuilding progress, the Department of Fisheries and Oceans monitors a group of key stocks selected to represent all British Columbia chinook stocks. The status and response to management actions of these stocks is evaluated by measuring, with known precision, either annual trends in escapement (escapement indicator stocks) or in escapement and total harvest (exploitation rate indicator stocks).

Harrison River chinook was designated an escapement indicator stock in 1984 for two reasons. First, the stock comprised almost one-third of the Fraser River system chinook escapement in the 1970s (Farwell *et al.* 1987). The status of this stock, therefore, is an important measure of the status of the Fraser River chinook resource. Second, as a white-fleshed, fall spawning stock with juveniles which migrate to sea immediately following emergence (Fraser *et al.* 1982), Harrison River chinook are unique in the Fraser River system. Individual monitoring, therefore, was warranted.

Previous reports have documented the 1984-90 Harrison River chinook enumeration studies (Staley 1990, Farwell *et al.* 1990, 1991). The current report documents the 1991 field methods, analytic techniques and study results, including estimates of adult age, length, sex, adipose fin clip (AFC) incidence, coded wire tag (CWT) recoveries, and escapement. The report concludes with a discussion of data limitations and recommendations for future studies.

STUDY AREA

The Harrison River is part of a complex system which drains a mountainous coastal watershed in southern British Columbia (Fig. 1). The river originates at Harrison Lake and flows southwest for 16.5 km, entering the Fraser River 116 km upstream from the Strait of Georgia. The river has an annual mean daily discharge of 449 m^3/s, with monthly mean daily flow maxima (947 m^3/s) and minima (202 m^3/s)(Environment Canada 1989) moderated by Lillooet and Harrison lakes.

The study area was divided into eight reaches based on homogeneity of physical characteristics (Fig. 2):

Reach 1 (Harrison Lake to km 9.5), extending from Harrison Lake downstream to Norris Creek, is characterized by a wide, low gradient channel with a depth of up to 10 m and a sandy substrate.

Reach 2 (km 9.5 to 7.7), extending to Billy Harris Slough and Reach 5 on the northwest and southeast banks, respectively, is similar to Reach 1 except water depth ranges to 3.0 m and the substrate is gravel.

Reach 3 (km 7.7 to 7.1), extending to a shear boom on the northwest bank, is characterized by a gradient higher then Reach 2 and a substrate of cobble and large gravel.

Reach 4 (km 7.1 to 6.3) includes the main channel and several side channels separated from the northwest shore by gravel bars. The main channel is similar to Reach 3, with smaller substrate in the side channels.

Reach 5 (km 7.7 to 6.3) is a large side channel characterized by a

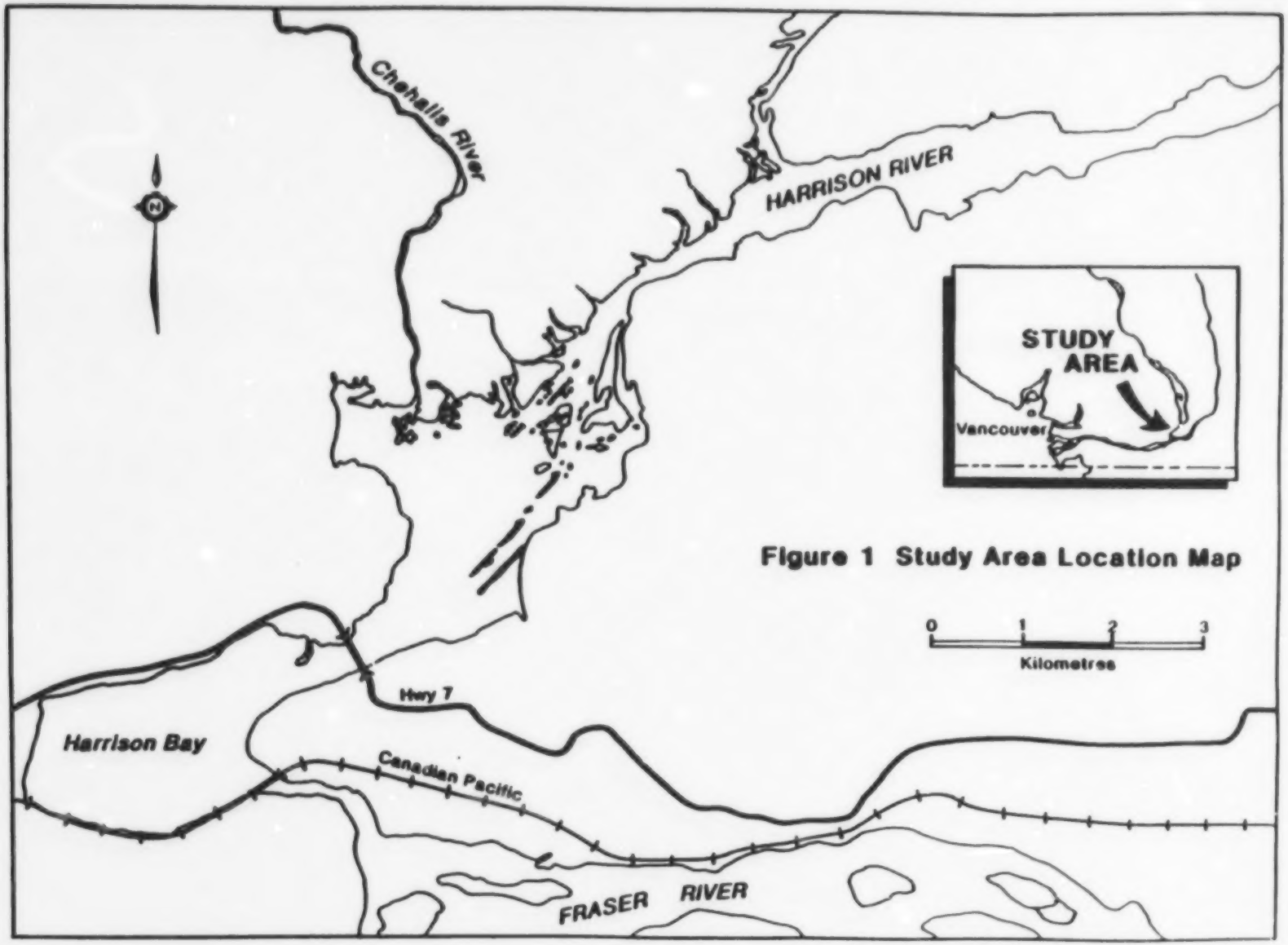

Figure 1 Study Area Location Map

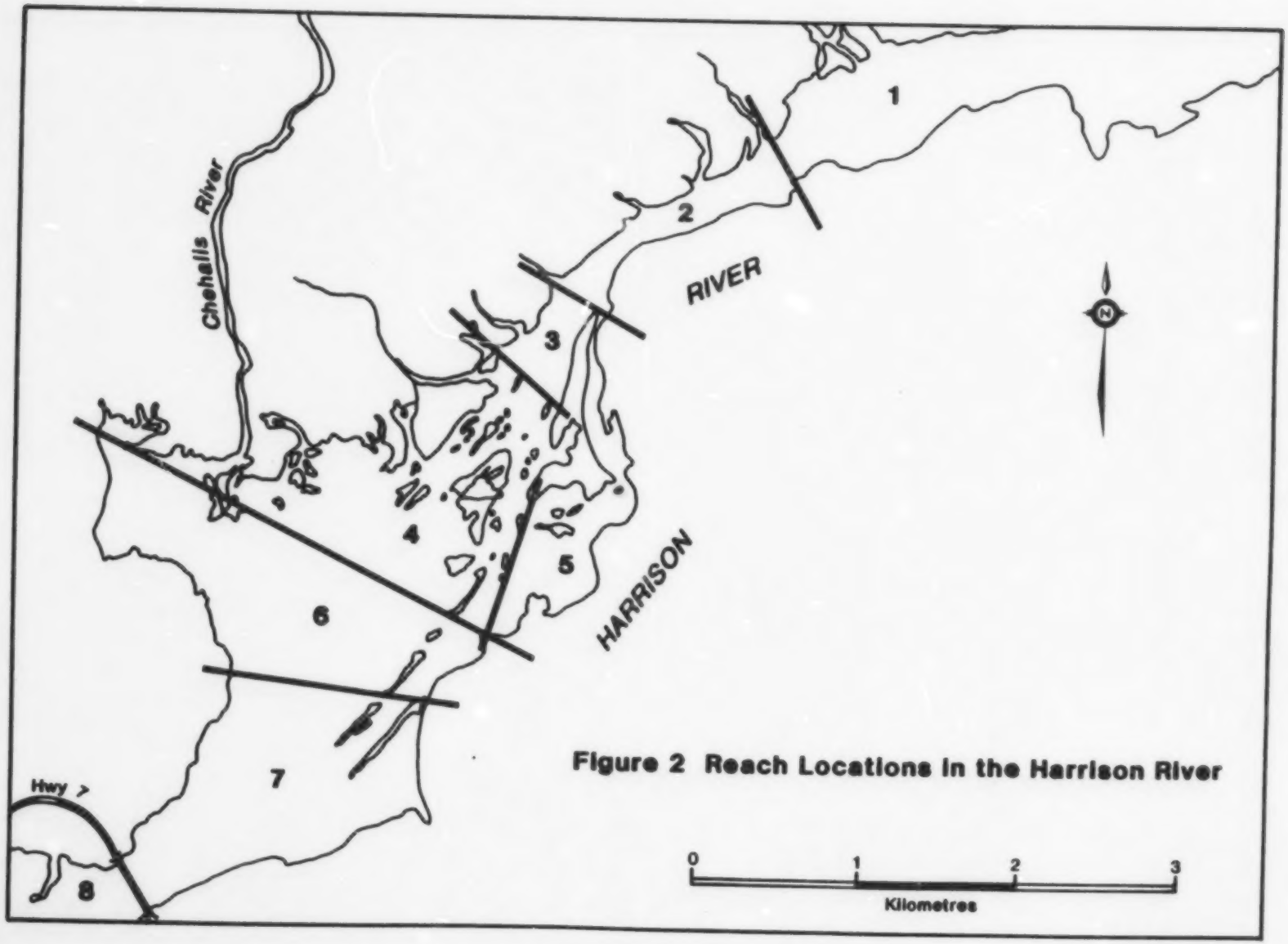

Figure 2 Reach Locations in the Harrison River

low gradient, a depth of up to 1.5 m, and a sand substrate. An island at the midpoint divides the reach into two sections.

Reach 6 (km 6.3 to 4.5), extending to a rock bluff on the southeast short (2 km upstream from the Highway 7 bridge), includes the main channel and part of the Chehalis River flood plain. The channel has a depth of up to 3 m and a substrate of bedrock and gravel.

Reach 7 (km 4.5 to 3.0), extending to the Highway 7 bridge, includes the main channel and part of the Chehalis River flood plain. The channel has a low gradient, a depth of up to 3 m and a mud substrate.

Reach 8 (km 3.0 to 0), which includes the main channel from the Highway 7 bridge to the Fraser River and Harrison Bay, is deep (up to 4 m) and slow, flowing over a sand and gravel substrate.

METHODS

FISH CAPTURE

Chinook adults were captured in reaches 2, 3, 4, and 6 from October 15 to November 22, 1991 using a 67 m x 6 m x 9 cm mesh seine net. The net was set by power boat in a downstream crescent, then withdrawn from the river to enclose a small area of water along the river bank. Captured chinook were held in the net until removed for tagging and release.

TAG APPLICATION

Spaghetti tags (ST's) were applied to chinook adults in a wooden tray constructed with a flexible plastic bottom and a meter stick recessed in one side. After tagging, chinook adults were released over a submerged section of the net; at no time were they removed from the water. Precocious males (jacks), defined as chinook less than 50 cm in nose-fork (NF) length, were released untagged.

The ST's consisted of a 50 cm long, 2 mm diameter hollow plastic tube numbered with a unique code. The tag was inserted with a 13 cm long stainless steel needle through the musculature and pterygiophore bones 2 cm below the anterior portion of the dorsal fin. The tag was tied tightly over the dorsal surface with a square knot.

Each tagged fish received a secondary mark to allow the assessment of ST loss. One or two 7 mm diameter holes were punched through the right operculum of males and females, respectively, using a single hole punch. Care was taken to avoid gill damage.

Date and location (reach) of capture, ST number, sex, NF length to the nearest 0.5 cm, and adipose fin status were recorded for each chinook released with a tag. Release condition was recorded as 1 (swam away vigorously), 2 (swam away sluggishly) or 3 (required ventilation).

SPAWNING GROUND SURVEYS

Weekly spawning ground surveys were conducted from October 23 to December 06, 1991. Complete surveys were conducted weekly by two-person crews, with two to four crews required depending on carcass abundance. The shore was surveyed on foot, while deep water areas were surveyed by boat.

Carcasses were recorded by date, reach, recovery type (shore or deep water), sex (confirmed by abdomen incision), and mark type (ST, secondary mark or AFC). Each marked carcass and every twentieth unmarked

carcass was sampled. All carcasses were cut in two with a machete and returned to the river. Sample data, recorded by date and reach, included postorbital-hypural plate (POH) length to the nearest 0.1 cm, sex, female spawning success (0%, 50%, or 100% spawned), adipose fin condition, and scales. For AFC chinook, the head was removed posterior to the eye orbit for later CWT identification. Adipose fin condition was recorded as unclipped or as complete (flush with dorsal surface), partial (nub present) or questionable (appeared clipped but fungus or decomposition obscured the area). The condition of AFC carcasses was recorded as fresh (gills red or mottled), moderately fresh (gills white, body firm), moderately rotten (body intact but soft), or rotten (skin and bones), and the absence of one or both eyes was noted.

ESCAPEMENT ESTIMATION

Total Escapement: The 1991 escapement of Harrison River chinook adults was calculated from the mark-recapture data using the Petersen formula (Chapman modification) (Ricker 1975). Total escapement was the sum of escapement by sex:

1) Estimated Harrison River chinook escapement (N_t):

$$N_t = N_m + N_f$$

where:

N_m = estimated escapement of adult males;

$$= \frac{(M_m + 1)(C_m + 1)}{(R_m + 1)}$$

N_f = estimated escapement of females, analogous to above.

2) Estimated 95% confidence limits of N_t:

$$N_t \pm 1.96 \sqrt{V_t}$$

where:

N_t = total escapement estimate;

V_t = variance of the escapement estimate;

$= V_m + V_f$

V_m = variance of the adult male escapement estimate;

$$= \frac{(N_m^2)(C_m - R_m)}{(C_m + 1)(R_m + 2)}$$

N_m = adult male escapement estimate;

C_m = number of adult male carcasses examined for ST's;

R_m = number of ST or secondary marked adult males recovered;

V_f = variance of female escapement estimate, analogous to above.

Sex Identification Correction: The ST application data were corrected for sex identification error. Error occurred because the development of sexually dimorphic traits was often not advanced and internal examinations could not be made. Correction of recovery data was unnecessary because all carcasses were incised and examined internally. Sex identification error was corrected as described by Staley (1990):

3) Estimated true number of males released with ST's and secondary marks (M_m):

$$M_m = \frac{M'_m - (M_t R_{m,f})/R_f}{1 - (R_{m,f}/R_f) - (R_{f,m}/R_m)}$$

where:

$\dot{M}_m$ = field estimate of number of males released with ST's and secondary marks;
M_t = total number of chinook adults released with ST's and secondary marks;
$R_{m,f}$ = number of females recovered with ST's which were released as males;
$R_{f,m}$ = number of males recovered with ST's which were released as females;
R_f = number of females recovered with ST's;
R_m = number of males recovered with ST's.

4) Estimated true number of females released with ST's and secondary marks (M_f):

$$M_f = M_t - M_m$$

Adipose Fin Clipped Escapement: The estimated AFC escapement was the product of the AFC incidence in the recovery sample, the largest of the two available samples, and the mark-recapture escapement estimate. Confidence limits and escapement by CWT code were not estimated because escapement was not stratified by age.

RESULTS

MARK-RECAPTURE

Tag Application

One thousand eight hundred seventy chinook adults were released with ST's and secondary marks from October 15 to November 22, 1991 (Appendix 1; Table 1). Release condition was good, with only nine (0.5%) requiring ventilation (Table 2). The proportion of this group recovered (0%) was not significantly different ($p > 0.05$; chi-square) from the unstressed group (3.1%). Consequently, fish requiring ventilation were not removed from the application sample.

An estimated 3.7% of the males and 3.2% of the females were misidentified at the time of tagging (Appendix 2). After adjustment for sex identification error, an estimated 1,087 (58.1%) males and 783 (41.9%) females were released with ST's and secondary marks (Table 1).

Spawning Ground Recovery

Three thousand seven hundred chinook adults were recovered on the spawning grounds from October 23 to December 06, 1991 (Table 1; Appendix 3). Of that total, 1,852 (50.1%) were male, 1,848 (49.9%) were female, 26 (0.7%) had AFCs, 56 (1.5%) had ST's and secondary marks, 16 (0.4%) had secondary marks only, and 2 (0.1%) had ST's only. Males (34.2%) lost ST's at a significantly higher rate than females (6.1%) ($p < 0.05$; chi-square).

SAMPLING SELECTIVITY

Period

Temporal bias in the application sample was examined by comparing between periods the mark incidence in the recovery sample (Table 3), where mark incidence was defined as the incidence of chinook adults marked with either a ST or secondary mark. Mark incidence, which ranged from 0.8% to 2.7%, was not different than expected ($p > 0.05$; chi-square).

Recovery bias was examined by stratifying the application sample by period and comparing proportions recovered (Table 4). Proportion recovered declined through the study; however, the trend was not significant ($p > 0.05$).

Table 1. Spaghetti tag application, carcass examination and mark recovery, by sex, of Harrison River chinook adults, 1991.

Sex	Spaghetti tags applied[a]	Carcasses examined	Marks recovered: Spaghetti tag and secondary mark	Marks recovered: Secondary mark only	Marks recovered: Spaghetti tag only	Marks recovered: Total	Percent recovered
Male	1,087	1,852	26	14	1	41	3.8%
Female	783	1,848	30	2	1	33	4.2%
Total	1,870	3,700	56	16	2	74	4.0%

[a] Adjusted for sex identification error.

Table 2. Spaghetti tag application and recovery of Harrison River chinook salmon, by release condition, 1991.

Release condition	Spaghetti tags applied	Spaghetti tags recovered	Percent recovered
Fish swam away without assistance	1,861	58	3.1%
Fish required ventilation	9	0	0.0%
Total	1,870	58	3.1%

Table 3. Incidence of spaghetti tags or secondary marks in chinook salmon recovered on the spawning grounds, by period, in the Harrison River, 1991.

Recovery period	Recovered with spaghetti tag or secondary mark		Total recovery		Mark incidence (%)
	Number	Percent	Number	Percent	
21 Oct to 28 Oct	1	1.4%	122	3.3%	0.8%
29 Oct to 05 Nov	15	20.3%	672	18.2%	2.2%
06 Nov to 13 Nov	19	25.7%	804	21.7%	2.4%
14 Nov to 21 Nov	15	20.3%	547	14.8%	2.7%
22 Nov to 29 Nov	9	12.2%	645	17.4%	1.4%
30 Nov to 07 Dec	12	16.2%	576	15.6%	2.1%
08 Dec to 15 Dec	3	4.1%	334	9.0%	0.9%
Total	74	-	3,700	-	2.0%

Table 4. Proportion of the spaghetti tag application sample recovered on the spawning grounds, by period, in the Harrison River, 1991.

Application period	Spaghetti tags applied	Spaghetti tags recovered[a]	Percent recovered
14 Oct to 20 Oct	642	29	4.5%
21 Oct to 27 Oct	437	10	2.3%
28 Oct to 03 Nov	58	2	3.4%
04 Nov to 10 Nov	640	16	2.5%
11 Nov to 17 Nov	79	1	1.3%
18 Nov to 24 Nov	14	0	0.0%
Total	1,870	58	3.1%

[a] Excludes 16 with secondary mark only.

Location

Spatial bias in the application sample was examined by comparing between sections the mark incidence in the recovery sample (Table 5). Mark incidence was significantly different than expected with a higher incidence (10.5%) in the upper section ($p < 0.05$; chi-square). Mark incidence in the lower and middle sections, where 99% of the carcasses were recovered, was identical.

Recovery bias was examined by stratifying the application sample by section and comparing proportions recovered (Table 6). No significant difference was noted ($p > 0.05$).

Fish Size

Size related bias in the application sample was assessed by comparing the continuous POH length frequency distributions of marked and unmarked spawning ground recoveries. No significant difference was noted in males or females ($p > 0.05$; Kolmogorov-Smirnov two sample test).

Recovery bias was assessed by partitioning the application sample into recovered and non-recovered components and comparing the continuous NF length frequency distributions of each. Significant differences were noted, with higher recovery of larger males and females ($p < 0.05$) (Table 7).

Fish Sex

Sex related bias in the application sample was assessed by comparing the sex ratio of the marked and unmarked spawning ground recoveries (Table 8). No difference was noted ($p > 0.05$; chi-square).

Recovery bias was assessed by partitioning the application sample into recovered and non-recovered components and comparing the sex composition in each (Table 8). No difference was noted ($p > 0.05$). Furthermore, there was no difference between female (4.2%) and male (3.8%) chinook adults released with marks and recovered on the spawning grounds ($p > 0.05$) (Table 1).

Recovery Method

Differential behaviour related to capture and tagging stress was examined by comparing the mark incidence in carcasses recovered on the shore (1.6%) and in deep water (1.3%) (Table 9). No significant difference ($p > 0.05$; chi-square) was noted.

Spawning Success

Differential behaviour related to capture and tagging stress was examined by comparing the spawning success of marked (96.8%) and unmarked (90.8%) females (Appendix 4). No significant difference was noted ($p > 0.05$; chi-square).

ESTIMATION OF SPAWNER POPULATION

Total Escapement

The 1991 escapement of Harrison River chinook adults, calculated from the mark-recapture data, was 90,638, with lower and upper 95% confidence limits of 70,712 and 110,564 (Table 10). The escapement of male and female chinook adults was 48,002 and 42,636, respectively.

Adipose Fin Clipped Escapement

Based on the chinook adult AFC incidence in the recovery sample (0.7%) (Appendix 3), the 1991 escapement of AFC adults was 637 chinook (Table 10). CWT escapement estimates were not determined because total escapement was not stratified by age; however, recoveries are summarized by

Table 5. Incidence of spaghetti tags and secondary marks, by reach and section, in the Harrison River spawning ground recovery sample, 1991.

Section	Reach	Carcasses examined		Carcasses recovered with spaghetti tags or secondary marks		Mark incidence (%)
		Number	Percent	Number	Percent	
Upper	Reach 1	0	0.0%	0	0.0%	-
	Reach 2	38	1.0%	4	5.4%	10.5%
	Total	38	1.0%	4	5.4%	10.5%
Middle	Reach 3	105	2.8%	6	8.1%	5.7%
	Reach 4	447	12.1%	5	6.8%	1.1%
	Reach 5	17	0.5%	0	0.0%	-
	Total	569	15.4%	11	14.9%	1.9%
Lower	Reach 6	728	19.7%	9	12.2%	1.2%
	Reach 7	944	25.5%	21	28.4%	2.2%
	Reach 8	1,421	38.4%	29	39.2%	2.0%
	Total	3,093	83.6%	59	79.7%	1.9%
Total	-	3,700	-	74	-	2.0%

Table 6. Proportion of the spaghetti tag application sample recovered on the spawning grounds, by application reach, in the Harrison River, 1991.

Reach	Tags applied	Tags recovered[a]	Percent recovered
Reach 2	1,136	40	3.5%
Reach 3	698	16	2.3%
Reach 4	24	2	8.3%
Reach 6	12	0	0.0%
Total	1,870	58	3.1%

[a] Excludes 16 with secondary mark only.

Table 7. Spaghetti tag application and recovery of Harrison River chinook adults, by nose-fork length, 1991.

Nose-fork length (cm)	Spaghetti tags applied	Carcasses recovered with spaghetti tags[a]	Percent recovered
50-59	61	0	0.0%
60-69	152	0	0.0%
70-79	372	9	2.4%
80-89	632	15	2.4%
90-99	506	26	5.1%
100-109	134	8	6.0%
110-119	13	0	0.0%
Total	1,870	58	3.1%

[a] Excludes 16 with secondary mark only.

Table 8. Sex composition of application and recovery samples of Harrison River chinook adults, 1991.

Sex		Application sample[a]			Recovery sample		
		Recovered	Not recovered	Total	Marked	Unmarked	Total
Male	Percent	55.4	58.2	58.1	55.4	49.9	50.1
	Number	41	1,046	1,087	41	1,811	1,852
Female	Percent	44.6	41.8	41.9	44.6	50.1	49.9
	Number	33	750	783	33	1,815	1,848
Total	Number	74	1,796	1,870	74	3,626	3,700

[a] Adjusted for sex identification error.

Table 9. Incidence of spaghetti tags and secondary marks in chinook carcasses recovered on the spawning grounds, by recovery method, in the Harrison River, 1991.

Method	Number recovered	Recovered with tags or secondary marks	Mark incidence (%)
Shore recovery	3,067	50	1.6%
Deep water recovery	633	8	1.3%
Total	3,700	58	1.6%

Table 10. Escapement estimates, by sex, for Harrison River chinook adults, 1991.

Sex	Escapement estimate	95% confidence limit	
		Lower	Upper
Male	48,002	33,818	62,186
Female	42,636	28,641	56,631
Total	90,638	70,712	110,564
AFC Adult	637	-	-

CWT code and sex in Appendix 5. Although predation, as indicated by eye loss, did not significantly influence CWT loss ($p > 0.05$) (Appendix 6), loss was significantly higher in rotten carcasses (62%) ($p < 0.05$; chi-square) and in carcasses with partial and questionable AFC's (83%) ($p < 0.05$). When those samples were excluded from the analysis, long term CWT loss was estimated at 25%

AGE, LENGTH AND SEX

The age composition of 164 chinook carcasses without AFCs was 29.9% age 3_1, 47.0% age 4_1 and 23.1% age 5_1 (Table 11); the age composition of females and males, respectively, was 20.2% and 42.9% age 3_1, 52.1% and 40.0% age 4_1, and 27.7% and 17.1% age 5_1. The age composition of 23 carcasses with AFCs was 30.4% age 3_1, 47.8% age 4_1 and 21.8% age 5_1 (Table 11). No errors were noted in the aging of chinook with CWTs.

Mean NF length of males and females in the application sample was 83.1 cm and 86.0 cm, respectively. Size at age is detailed in Appendix 7. Mean POH lengths of males and females in the recovery sample were 70.3 cm and 71.6 cm, respectively (Appendix 7).

Females comprised 42.0% of the application sample, 56.6% of the recovery sample (Table 8) and 47.0% of the population estimate.

DISCUSSION

ADULT CAPTURE TECHNIQUE

A basic assumption underlying Petersen mark-recapture studies is that capture and tagging do not influence the subsequent catchability of the fish. We evaluated this factor in two ways. First, we compared the mark incidence in carcasses recovered on the shore and in deep water main channel areas. We assumed that stressed fish would move passively downstream, with the most stressed individuals dying and being differentially recovered in main channel areas. Because no difference was noted, and because mark incidence was not high in the lower reaches, we believe differential loss of marked fish was minor. Second, we compared the spawning success in spaghetti tagged and untagged females. Because there was no significant difference in spawning success, we concluded that capture and marking did not influence subsequent behaviour. This was consistent with 1990 study results (Farwell *et al.* 1991)

SAMPLING SELECTIVITY

A second assumption underlying Petersen mark-recapture studies is that the population is sampled in a random or representative manner (Ricker 1975). In studies when non-representative sampling occurs, accurate results may still be achieved if one sample is representative (Robson 1969). As in previous studies, it was not possible to test for representativeness because the true population parameters were not known. Instead, we examined the samples for four biases, temporal, spatial, fish size, and fish sex, as indicators of weakness in the study design. Biases were identified in both the application (spatial bias) and recovery (bias to large fish) samples (Table 12). We could not conclude, however, that these bias had biased the escapement estimate. The spatial bias, while present in the application sample, was not noted in the recovery sample. The fish size bias, present in the recovery sample, was not observed in the application sample. Because bias can exist in both samples without biasing the population estimate if the sources of bias were independent (Junge 1963),

Table 11. Age composition of chinook carcasses recovered on the spawning grounds, by adipose fin and CWT status, in the Harrison River, 1991.

Age	Adipose fin present			Adipose fin absent		
	Male	Female	Total	Male	Female	Total
3_1	42.9%[a]	20.2%	29.9%	83.3%	11.8%	30.4%
4_1	40.0%	52.1%	47.0%	0.0%	64.7%	47.8%
5_1	17.1%	27.7%	23.1%	16.7%	23.5%	21.8%
Sample Size	70	94	164	6	17	23

a. Includes one male age 3_1 which was not measured for POH length.

Table 12. Summary of results of statistical tests for bias in the 1991 Harrison River escapement estimation study. [a]

Test	Application sample	Recovery sample
Period	No bias	No bias
Location	Bias to Reach 2	No bias
Fish size	No bias	Bias to larger fish
Fish sex	No bias	No bias
Recovery method	-	No bias

a. No bias indicates bias was not detected; undetected bias may be present.

we concluded that sampling selectivity was unlikely to have introduced significant bias in the 1991 Harrison River chinook escapement estimate.

ESCAPEMENT TRENDS

The Harrison River mark-recapture study was implemented in 1984 to monitor the rebuilding expected from management actions implemented after the signing of the Pacific Salmon Treaty. Escapements since 1984 have not been consistent with the response expected under the rebuilding program. Although escapements have been variable, the average escapement has declined relative to 1984. The 1991 escapement estimate of 90,638 is below the 1984 to 1990 average escapement of 117,775 and only 38% the 1998 escapement goal of 241,700.

SUMMARY

1. The Harrison River chinook stock is one of a group of British Columbia chinook stocks being monitored to evaluate escapement responses to management actions implemented under the Pacific Salmon Treaty.

2. Adult spawners were enumerated by a mark-recapture study from October 15 to December 06, 1991. Chinook adults were captured using a beach seine and marked with spaghetti tags and opercular punches. The escapement was censused by the recovery of carcasses following spawning.

3. The 1991 chinook adult escapement was estimated from a spaghetti tag application sample of 1,870, a recovery sample of 3,700, and a recovery of 74 carcasses with spaghetti tags or secondary marks. The estimated escapement was 90,638 chinook adults, of which 42,636 were female and 48,002 were male, and 637 had adipose fin clips.

4. The age composition, measured from the recovery sample, was:

	3_1	4_1	5_1
Female	19%	54%	27%
Male	45%	37%	17%

POH length averaged 71.6 cm for females and 70.3 for males.

5. Biases were identified in both the application and recovery samples; however, we were unable to conclude that the 1991 escapement estimate was biased.

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REFERENCES

Anon. 1985. An agreement between the Government of Canada and the Government of the United States of America concerning Pacific salmon. 36 p.

Environment Canada. 1989. Historic streamflow summary British Columbia to 1988. Water Survey of Canada. 1056 p.

Farwell, M.K., N.D. Schubert, K.H. Wilson, and C.R. Harrison. 1987. Salmon escapements to streams entering statistical areas 28 and 29, 1951 to 1985.

Can. Data Rep. Fish. Aquat. Sci. 601: 166 p.

Farwell, M.K., N.D. Schubert, and L.W. Kalnin. 1990. Enumeration of the 1989 Harrison River chinook salmon escapement. Can MS Rep. Fish. Aquat. Sci. 2078: 24 p.

Farwell, M.K., N.D. Schubert, and L.W. Kalnin. 1991. Enumeration of the 1990 Harrison River chinook salmon escapement. Can Manuscr. Rep. Fish. Aquat. Sci. 2111: 26 p.

Fraser, F.J., P.J. Starr, and A.Y. Fedorenko. 1982. A review of the chinook and coho salmon of the Fraser River. Can. Tech. Rep. Fish. Aquat. Sci. 1126: 130 p.

Junge, C.O. 1963. A quantative evaluation of the bias in population estimates based on selective samples. Int. Comm. North Atl. Fish. Spec. Pub. No. 4: 26-28.

Ricker, W.E. 1975. Computations and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board Can. 191: 382 p.

Robson, D.S. 1969. Mark-recapture methods of population estimation. In New Developments in Survey Sampling. N.C. Johnson and H. Smith, Jr. (eds.). Wiley-Interscience, Wiley and Sons. New York.

Staley, M.J. 1990. Abundance, age, size, sex and coded wire tag recoveries for chinook salmon escapements of the Harrison River, 1984-1988. Can. MS Rep. Fish. Aquat. Sci. 2066: vii + 42 p.

APPENDICES

Appendix 1. Chinook adult spaghetti tag application, by adipose fin status and sex, in the Harrison River, 1991. a

		Adipose present			Adipose absent			Total		
Date	Reach	Male	Female	Total	Male	Female	Total	Male	Female	Total
15-Oct	2	69	57 b	126	0	0	0	69	57	126
16-Oct	2	66	50	116	0	0	0	66	50	116
17-Oct	2	138	113	251	2	1	3	140	114	254
18-Oct	2	90	53	143	1	2	3	91	55	146
21-Oct	2	93	52	145	1	2	3	94	54	148
22-Oct	2	79	49	128	0	2	2	79	51	130
23-Oct	2	37	28	65	0	1	1	37	29	66
24-Oct	2	26	12	38	2	1	3	28	13	41
	4	3	3	6	0	0	0	3	3	6
25-Oct	2	25 b	20	45	1	0	1	26	20	46
28-Oct	2	20	11	31	1	0	1	21	11	32
01-Nov	2	15	11	26	0	0	0	15	11	26
04-Nov	2	2	2	4	0	0	0	2	2	4
	3	120	104	224	1	2	3	121	106	227
05-Nov	3	108 c	81	189	4	1	5	112	82	194
06-Nov	3	81 b	75 b	156	1	1	2	82	76	158
07-Nov	2	0	1	1	0	0	0	0	1	1
	3	43 b	13	56	0	0	0	43	13	56
12-Nov	3	32	26	58	0	0	0	32	26	58
13-Nov	3	2	2	4	0	0	0	2	2	4
15-Nov	3	1	0	1	0	0	0	1	0	1
	4	11	5	16	0	0	0	11	5	16
18-Nov	4	0	1	1	0	0	0	0	1	1
	6	8	4	12	0	0	0	8	4	12
22-Nov	4	1	0	1	0	0	0	1	0	1
Total	2	660	459	1,119	8	9	17	668	468	1,136
	3	387	301	688	6	4	10	393	305	698
	4	15	9	24	0	0	0	15	9	24
	6	8	4	12	0	0	0	8	4	12
Total	-	1,070	773	1,843	14	13	27	1,084	786	1,870

a. Not corrected for sex identification errors.
b. One required ventilation.
c. Four required ventilation.

Appendix 2. Spaghetti tag recoveries in the Harrison River, by application and recovery date and location, 1991.

Application sample					Recovery sample				
Date	Reach	NF length (cm)	Sex	Adipose fin	Date	Reach	POH length (cm)	Sex	Days out
15-Oct	2	87.5	M	P	07-Nov	8	70.4	F a	23
15-Oct	2	82.0	M	P	06-Nov	7	63.2	M	22
15-Oct	2	99.0	M	P	01-Nov	7	77.5	M	17
15-Oct	2	97.0	F	P	01-Nov	4	76.0	F	17
15-Oct	2	75.5	M	P	13-Nov	7	59.3	M	29
16-Oct	2	92.6	F	P	01-Nov	7	76.0	F	16
16-Oct	2	87.0	F	P	04-Nov	6	70.9	F	19
16-Oct	2	94.0	F	P	05-Nov	4	75.4	F	20
16-Oct	2	82.0	M	P	13-Nov	7	64.4	M	28
16-Oct	2	92.0	F	P	01-Nov	7	72.0	F	16
16-Oct	2	93.0	M	P	31-Oct	8	74.5	M	15
17-Oct	2	100.0	F	P	05-Nov	6	81.2	F	19
17-Oct	2	89.5	F	P	30-Oct	6	71.8	F	13
17-Oct	2	93.0	F	P	23-Oct	4	74.7	F	6
17-Oct	2	93.5	F	P	01-Nov	7	76.5	F	15
17-Oct	2	100.0	M	A	02-Dec	7	77.7	M	46
17-Oct	2	104.0	F	P	20-Nov	7	85.5	F	34
17-Oct	2	91.0	M	P	12-Nov	8	71.9	M	26
17-Oct	2	83.5	F	P	01-Nov	7	69.0	F	15
17-Oct	2	76.0	F	P	01-Nov	7	61.6	F	15
17-Oct	2	81.5	F	P	20-Nov	7	67.5	F	34
17-Oct	2	92.0	M	P	08-Nov	3	75.6	M	22
17-Oct	2	78.0	F	P	04-Nov	7	61.9	F	18
17-Oct	2	73.0	F	P	01-Nov	7	59.2	F	15
18-Oct	2	89.5	F	A	01-Nov	7	72.6	F	14
18-Oct	2	107.0	F	P	19-Nov	8	84.7	F	32
18-Oct	2	96.0	F	P	05-Nov	4	71.2	F	18
18-Oct	2	95.0	M	P	31-Oct	8	64.1	M	13
18-Oct	2	94.5	F	P	01-Nov	7	76.1	F	14
21-Oct	2	104.0	M	P	12-Nov	8	79.2	M	22
22-Oct	2	91.0	F	P	07-Nov	8	73.8	F	16
22-Oct	2	93.5	M	P	25-Nov	8	72.2	M	34
22-Oct	2	93.0	F	P	07-Nov	8	73.8	F	16
23-Oct	2	86.0	F	P	14-Nov	6	68.6	F	22
23-Oct	2	93.5	F	P	19-Nov	8	74.5	F	27
24-Oct	2	94.5	F	P	13-Nov	7	76.0	F	20
24-Oct	4	82.0	F	P	13-Nov	7	65.9	M a	20
25-Oct	2	87.0	F	P	25-Nov	8	68.1	F	31
25-Oct	2	96.0	F	P	25-Nov	8	71.2	F	31
01-Nov	2	86.0	M	P	29-Nov	8	69.3	M	28
01-Nov	2	77.5	F	P	14-Nov	3	63.8	F	13
04-Nov	3	105.5	M	P	08-Nov	6	82.5	M	4
04-Nov	3	98.0	M	P	08-Nov	2	75.0	M	4
04-Nov	3	82.5	F	P	29-Nov	8	67.0	F	25
04-Nov	3	73.5	M	P	29-Nov	8	0.0	M	25
04-Nov	3	76.5	M	P	19-Nov	8	61.2	M	15
04-Nov	3	90.0	M	P	05-Nov	6	71.3	M	1
05-Nov	3	100.5	F	P	14-Nov	3	82.3	F	9
05-Nov	3	96.5	M	P	08-Nov	2	74.2	M	3
05-Nov	3	107.5	M	P	08-Nov	2	82.4	M	3
05-Nov	3	81.0	F	P	26-Nov	7	64.2	F	21

Appendix 2. Spaghetti tag recoveries in the Harrison River, by application and recovery date and location, 1991.

Application sample					Recovery sample				
Date	Reach	NF length (cm)	Sex	Adipose fin	Date	Reach	POH length (cm)	Sex	Days out
05-Nov	3	74.0	M	P	08-Nov	3	59.4	M	3
06-Nov	3	93.0	M	P	14-Nov	3	73.5	M	8
06-Nov	3	83.0	M	P	13-Nov	7	65.6	M	7
06-Nov	3	74.5	M	P	25-Nov	8	59.8	M	19
07-Nov	3	94.0	M	P	14-Nov	3	75.4	M	7
07-Nov	3	93.0	M	P	08-Nov	2	69.9	M	1
15-Nov	4	91.5	M	P	04-Dec	7	71.8	M	19

Females initially identified as males: 1 3.2%
Males initially identified as females: 1 3.7%

Mean days out: 18.0
Maximum days out: 46
Minimum days out: 1

POH and NF Regressions:

Males
POH = 0.69 NF + 8.53
NF = 1.29 POH - 0.36

Females
POH = 0.75 NF + 4.43
NF = 1.22 POH + 2.16

a. Incorrect sex identification during disk tag application.

Appendix 3. Chinook carcass recoveries, by mark status and sex, in the Harrison River, 1991.

Date	Reach	Unmarked		Secondary mark only		Spaghetti tag and secondary mark		Total		Adipose absent	
		Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
23-Oct	3	1	0	0	0	0	0	1	0	0	0
	4	2	2	0	0	0	1	2	3	0	0
	5	3	6	0	0	0	0	3	6	0	0
	6	20	16	0	0	0	0	20	16	0	0
24-Oct	3	1	3	0	0	0	0	1	3	0	0
	4	9	12	0	0	0	0	9	12	0	0
	6	0	1	0	0	0	0	0	1	0	0
25-Oct	6	8	5	0	0	0	0	8	5	0	0
	7	8	6	0	0	0	0	8	6	0	0
	8	9	9	0	0	0	0	9	9	0	0
30-Oct	4	42	70	0	0	0	0	42	70	0	1 a
	6	53	69	0	0	0	1	53	70	0	1
	7	36	31	0	0	0	0	36	31	0	0
31-Oct	8	97	32	2	0	2	0	101	32	2	0
01-Nov	3	6	10	0	0	0	0	6	10	0	0
	4	1	2	0	0	0	1	1	3	0	0
	5	5	1	0	0	0	0	5	1	0	0
	6	9	4	0	0	0	0	9	4	1	0
	7	109	80	0	0	1	8	110	88	1	1
04-Nov	6	42	37	0	0	0	1	42	38	0	0
	7	18	14	0	0	0	1	18	15	0	0
05-Nov	4	20	47	1	0	0	2	21	49	0	0
	6	46	33	0	0	1	1	47	34	0	0
06-Nov	7	55	46	0	0	1	0	56	46	0	1
07-Nov	8	104	49	1	0	0	3	105	52	0	1
08-Nov	2	17	16	0	0	4	0	21	16	0	0
	3	15	42	0	0	2	0	17	42	0	1
	4	51	84	0	0	0	0	51	84	2	0
	6	17	32	0	0	1	0	18	32	0	0
12-Nov	8	106	58	1	0	2	0	109	58	0	0
13-Nov	6	24	37	2	0	0	0	26	37	0	0
	7	95	72	0	0	4	1	99	73	0	0
14-Nov	3	7	12	0	0	2	2	9	14	0	0
	4	11	33	0	0	0	0	11	33	0	0
	6	25	52	0	0	0	1	25	53	0	2 a
19-Nov	5	0	2	0	0	0	0	0	2	0	0
	6	3	3	0	0	0	0	3	3	0	0
	8	206	203	4	0	1	2	211	205	1	1
20-Nov	6	5	1	0	0	0	0	5	1	0	0
	7	64	51	0	0	0	2	64	53	0	0
21-Nov	4	4	17	0	0	0	0	4	17	0	0
	6	25	47	0	0	0	0	25	47	0	0
22-Nov	2	1	0	0	0	0	0	1	0	0	0
	3	1	1	0	0	0	0	1	1	0	0
	4	0	2	0	0	0	0	0	2	0	0
25-Nov	8	108	92	3	0	2	2	113	94	0	2
26-Nov	4	4	5	0	0	0	0	4	5	0	0
	5	0	0	0	0	0	0	0	0	0	0
	6	3	19	0	1	0	0	3	20	0	0
	7	48	55	0	0	0	0	48	56 b	0	3
27-Nov	4	2	6	0	0	0	0	2	6	0	0
	6	12	21	0	0	0	0	12	21	0	0

Appendix 3. Chinook carcass recoveries, by mark status and sex, in the Harrison River, 1991.

		Unmarked		Secondary mark only		Spaghetti tag and secondary mark		Total		Adipose absent	
Date	Reach	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
27-Nov	7	0	2	0	0	0	0	0	2	0	0
29-Nov	8	108	79	0	0	1	1	110 b	80	0	0
02-Dec	4	0	1	0	0	0	0	0	1	0	0
	6	6	20	0	0	0	0	6	20	0	0
	7	53	57	0	0	1	0	54	57	1	2
	8	23	28	0	0	0	0	23	28	0	1
03-Dec	3	0	0	0	0	0	0	0	0	0	0
	4	3	12	0	0	0	0	3	12	0	0
	6	2	7	0	0	0	0	2	7	0	0
04-Dec	7	10	11	0	0	1	0	11	11	0	0
	8	40	33	0	1	0	0	40	34	1	0
06-Dec	6	5	10	0	0	0	0	5	10	0	0
	7	2	0	0	0	0	0	2	0	0	0
	8	1	7	0	0	0	0	1	7	0	0
Total	2	18	16	0	0	4	0	22	16	0	0
	3	31	68	0	0	4	2	35	70	0	1
	4	149	293	1	0	0	4	150	297	2	1
	5	8	9	0	0	0	0	8	9	0	0
	6	305	414	2	1	2	4	309	419	1	3
	7	498	425	0	0	8	12	506	437 c	2	7
	8	802	590	11	1	8	8	821 c	599	4	5
Total	-	1,811	1,815	14	2	26	30	1,851	1,847	9	17

a. One questionable AFC.
b. Includes one spaghetti tag only.

Appendix 4. Spawning success of female chinook spawning ground recoveries, by mark status, in the Harrison River, 1991.

		Percent spawned			
		0%	50%	100%	Weighted mean
Spaghetti tag or secondary mark	Number	1	0	30	
	Percent	3.2%	0.0%	96.8%	96.8%
Unmarked	Number	8	0	80	
	Percent	9.1%	0.0%	90.9%	90.9%
Total	Number	9	0	110	
	Percent	7.6%	0.0%	92.4%	92.4%

Appendix 5. CWT spawning ground recoveries in the Harrison River, 1991.

CWT Code	Release site	Brood year	CWTs Recovered		
			Male	Female	Total
2 44 02	Chehalis R.	1986	1	0	1
2 44 04	Chehalis R.	1986	0	1	1
2 44 07	Chehalis R.	1986	0	1	1
2 44 09	Chehalis R.	1986	1	0	1
2 47 38	Chehalis R.	1987	0	1	1
2 47 39	Chehalis R.	1987	1	0	1
2 47 40	Chehalis R.	1987	0	2	2
2 47 41	Chehalis R.	1987	0	1	1
2 57 47	Chilliwack R.	1988	1	0	1
2 57 61	Chehalis R.	1988	1	1	2
2 57 62	Chehalis R.	1988	2	0	2
Total CWT carcasses			7	7	14
AFC Carcasses with no CWT			2	10 a	12
Total AFC carcasses			9	17	26

a. Includes one with no head

Appendix 6. Incidence of CWT loss by carcass condition, eye status, and AFC condition in AFC chinook adult carcasses in the Harrison River, 1991.

Part	Condition	Number	CWT absent	CWT loss (%)
Carcass condition	Fresh	4	1	25.0%
	Moderately fresh	9	2	22.2%
	Moderately rotten	12	7	58.3%
	Rotten	1	1	100.0%
Eyes	Present	13	5	38.5%
	Absent	13	6	46.2%
Adipose fin clip	Complete	20	6	30.0%
	Partial	4	4	100.0%
	Questionable	2	1	50.0%

Appendix 7. Mean lengths by age and sex for Harrison River chinook salmon, 1991.

Sample	Age	Sex	Sample Size	Percent	Length (cm) Mean	Standard deviation	Range
Application a,b	-	Male	1,084	58.0%	83.1	13.4	51.0 - 114.0
		Female	786	42.0%	86.0	7.9	51.5 - 109.0
		Total	1,870	-	84.3	11.5	51.0 - 114.0
Recovery c	3/1	Male	34	18.3%	64.3	5.0	52.5 - 74.5
		Female	21	11.3%	65.0	3.9	56.8 - 72.3
	4/1	Male	28	15.1%	73.3	6.2	57.4 - 82.0
		Female	60	32.3%	71.8	5.2	59.5 - 85.5
	5/1	Male	13	7.0%	79.6	5.3	71.1 - 88.8
		Female	30	16.1%	75.4	4.2	68.1 - 83.2
	Total	Male	92	43.4%	70.3	8.1	52.5 - 88.8
		Female	120	56.6%	71.6	6.2	56.3 - 85.5
		Total	212	-	71.0	7.1	52.5 - 88.8

a. Not adjusted for sex identification errors.
b. Nose-fork length.
c. Postorbital-hypural length.